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ABSTRACT

The purpose of this paper is to select from among the bodies of research on complex skill learning those generalizations that seem to have some applicability to issues in designing training materials for teacher education. That selection entails a review of the principal points and findings within the domain and of the implications of the findings for the development of training materials for teacher education. The first section of the paper delineates the characteristics of skilled performance and briefly examines the stages that the learners pass through as they acquire such skills. Three variables are identified--instructions, practice, and knowledge of results--that have been widely investigated and that are applicable to training materials. Summarized are some of the principal generalizations about these variables, especially as they seem to pertain to the ultimate objective of designing training materials. The second section of the paper deals with an analysis of skilled performance in teaching and extrapolates from the research on complex skills learning how one might design training materials in the area of the teaching of concepts. (Author/DDO)

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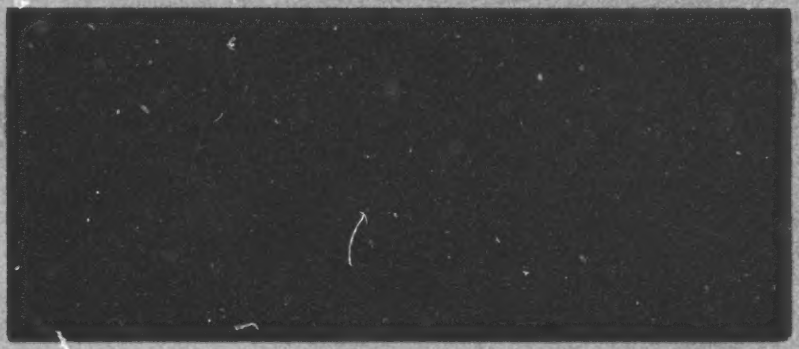
Acquiring Teaching Competencies:

Reports and Studies



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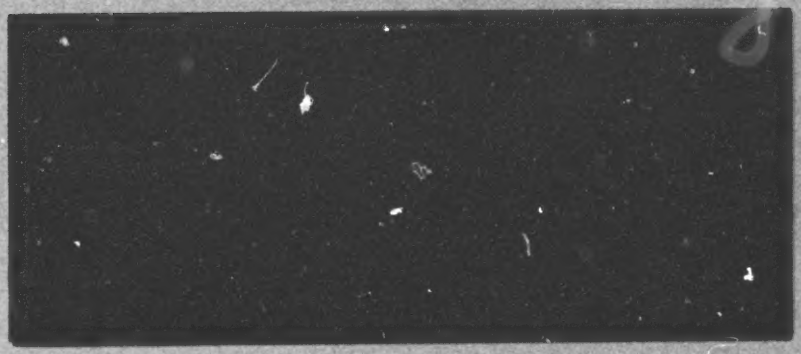

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Self-Contained Training Materials for Teacher Education: A Derivation from Research on the Learning of Complex Skills

Bryce B. Hudgins

Report # 5, February, 1974

SP 007 745

FOREWORD

In a previous article, Professor Hudgins investigated the research on concept acquisition and from that literature constructed a well-reasoned procedure for the development of protocol materials. Using a parallel strategy, Professor Hudgins has surveyed the research on complex skill learning to see if it is possible to extrapolate from that research meaningful guidelines to developers who are interested in materials which lead to the acquisition of teaching skills.

In pursuing this task three categories of variables in skill acquisition are defined which then serve as the primary foci around which generalizations are extracted from the research. These categories are (a) instructional variables, (b) practice variables, and (c) feedback (knowledge of results) variables. An illustrative skill is then analyzed in terms of a series of sub-skills derived from research on that particular skill. In this instance the teaching skill chosen for analysis is that of the "teaching of concepts." At this point, Professor Hudgins conjoins the two analytic efforts and attempts to apply the generalizations gleaned from the research on complex skills and the research on the teaching of concepts to produce propositions about the elements of teacher training materials and something of the character of those elements.

Perhaps one of the more interesting contributions of the author may be his concept of "self-contained teacher training materials." Professor Hudgins argues initially that skill in teaching anything must be based upon an empirically grounded model of that teaching skill. In this case, the model would be one of the "teaching of concepts." This model must be taught and learned as a kind of cognitive phase of skill development (perhaps the words "protocol phase" could be substituted for "cognitive phase"). The second phase involves the "self-contained training materials." Materials in this phase include opportunity for extended practice with feedback in a way that does not involve all the complexities of the actual field context. Instead the practice entails a minimum of external support in the sense of equipment, personnel, etc. It strives for efficiency in practice and feedback conditions rather than realism, an interesting and perhaps controversial idea.

The final part of the paper takes the concepts of "longitude" and "latitude" and outlines in general the form which the training materials would take with respect to the instructions to be given the teacher trainee, the conditions of practice, and the kind of feedback which would be appropriate.

In my opinion, the article constitutes not only an interesting set of guidelines to the developer but also a model of the uses to which the research literature can be put in the development of such guidelines.

L. D. Brown, Editor

Self-Contained Training Materials for Teacher Education: A Derivation from Research on the Learning of Complex Skills

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The purpose of this paper is to select from among the bodies of research on complex skill learning those generalizations that seem to have some applicability to issues in designing training materials for teacher education. That selection entails a review of the principal points and findings within the domain, and implications of the findings for the development of training materials for teacher education. The paper is structured as follows. In the first section, we begin by delineating the characteristics of skilled performance and briefly examine the stages that learners pass through as they acquire such skills. Then, we identify three variables -- instructions, practice and knowledge of results -- that have been widely investigated and which are applicable to training materials. We summarize some of the principal generalizations about these variables, especially as they seem to pertain to our more ultimate objective of designing teacher training materials. The second section of the paper is concerned with an analysis of skilled performance in teaching and some admitted extrapolations from the research on complex skills learning to how one might design training materials for teacher education. In an effort to produce discussion at a level commensurate with the problems of such development, we shall try to extrapolate the principles of

skill learning to the issues of designing training materials in the area of the teaching of concepts.

The Dimensions and Learning of Complex Skills.

Characteristics of Skilled Performance

What characterizes the performance of an individual who possesses a skill in great abundance? A description will help us to see what kinds of criteria we want to impose upon the design of training materials in order that they may lead to appropriate outcomes. The game performance of an accomplished athlete makes a good beginning point for this analysis. On a baseball team, for example, the most skilled fielder is commonly placed at the shortstop position. On a ground ball hit hard to the right of the shortstop into the deep position, or the "hole", as it is called, the player must move at a sprint from his normal placement in the direction opposite to that where he must throw (first base). Ordinarily, when he grasps the ball, his momentum is carrying him away from the direction of his throw. He must turn, off balance, and throw forcefully if he is to beat the runner to first base with the ball. Sometimes, the throw is made while the player is off the ground, turning in mid-air to face in the direction that he throws. Of course, this performance is only executed successfully by the best players, and not always by them.

If we examine records of such performances, or more mundane ones, certain characteristics of the skilled performance emerge. For one thing, the timing of the performance is good. Whatever the demands of the performance or some element of it, the performer seems to have plenty of time to do what he wishes to do, or must do. Some years ago, my wife and I joined a square dance group. The initiation into this organization in-

volved a series of lessons, some eight or perhaps ten of them, one evening a week. If you have ever square danced, you know that the one thing you do very little is to stand around. Square dancers seem always to be on their way from one place to another and, of course, they have a precise number of measures to arrive at the proper next station. There are many ways to distinguish between a novice and a veteran square dancer, but I have found the most reliable one is to assess where each is, in relation to his destination, on the beat before the last beat. You will invariably find the accomplished dancer one rather jaunty stride from where he is heading, and the beginner either standing around sheepishly where he was headed for (or thought he should be headed for) or a mile down the road, coming hell bent for election. Let me anticipate the discussion a bit here and indicate that one of the things the beginner most requires is a cognitive map of the skill. As I say, we shall return to that idea shortly.

The skilled performer also has an advantage over the beginner in that he can <u>anticipate</u> what is to come. With proficient typists or telegraphers this amounts to the ability to group larger chunks of information before beginning to type or to transmit. Sometimes this is referred to as the ability to "copy behind." In square dancing, to continue that metaphor, the veteran dancer has in mind that after the present maneuver, the dance will shift to an "allemande left." A firm knowledge, not only of the segment he is now dancing but also of the position of his body, arms, and hands when he hits the corner, permits him to swing his partner with vigor and come around, arm bent just so, headed down the line, set for the allemande. To the beginner, on the other hand, each movement is new, not quite learned. It still represents a significant challenge to him just to get through the "now" moment, never mind the fancy footwork that lies

ahead.

The skillful performer has long since eliminated false moves, unnecessary little steps and starts that impede, if not the actual effectiveness of his performance, its stylistic or elegant nuances. This accounts in part for his ability to be in the right place at the right time and to anticipate the next set of events. Finally, most skilled performances become automatic or autonomous. Thus, the typist fully habituated to dealing with mounds of manuscript copy may pound happily away at the day's work, averaging eighty or ninety words a minute over long stretches of hours, and with only an occasional error. Such a performance is enough to astound the beginning high school student of typing with his low speed and seemingly endless string of mistakes. However, even the expert suddenly encounters not the neat rows of manuscript copy but, let us say, tables of detailed data, tables that demand the most exact duplication lest their meaning be altered. It is at this point that the responses of the expert are challenged. No longer can the typist think about her menu for that evening, or what dress she will wear to the weekend party. As the difficulty level of the task increases, her attention to the task is demanded. Similarly, to bring the point home, you may be driving along the highway, responding automatically to the fairly constant stimulus conditions of the road, signals, light and weather conditions, when suddenly a large, slow moving truck pulls from a side road immediately into the path of your car. At once, the automatic quality of your driving is replaced by intense attention to the details of the situation. You may have to call upon all the skill your years of experience as a driver have provided you with to avoid a serious accident. Again, what differentiates the skilled performer from the novice is that, in critical situations, the skilled

performer is able to bring his capabilities to bear upon the situation, to avoid an accident, to throw out a speedy runner, to contribute to the graceful flow of a square dance, or to teach a concept in a situation that presents unusual aspects.

Fitts (1962), in his analysis of complex skills, breaks their learning into a series that, while it is similar to what we have just said, also adds a dimension that is particularly pertinent for people involved in producing training materials that are more clearly verbal and cognitive in composition than they are simply motoric or even perceptual. Thus, Fitts says that three overlapping stages occur as complex skills are mastered. First is a cognitive phase, followed by a phase of fixation, and finally an autonomous phase. The last two are similar to our previous discussion. Most important, however, is Fitts' identification of a cognitive phase in the learning of complex skills. In short, this means that in the beginning what the learner requires is a cognitive map of the skill he is to learn how to perform. This would include some specification, when pertinent, of the purposes of the skill, what he will accomplish by performing it. For example, with respect to materials for teacher education, you might wish to communicate to the student the relationship between the skill to be learned, and other more complex skills, or how this skill will enable him to overcome a traditionally difficult phase of teaching, or something of the sort.

But more directly, the cognitive phase involves helping the learner to specify the elements of the performance, what sequence is demanded or what options may exist with respect to sequences, and, in general, the nature of the final performance. In a very real sense, this is a time when the learning of the student can be facilitated by assisting him to

form a concept of what is contained in the skill, how its elements fit together, and how his present knowledge and experience can contribute (that is, transfer positively) to what he is to learn.

Instructions

When we want someone to learn a new skill, naturally one of the first things that occurs to us is to provide some kind of instructions for the learner. At one level, these instructions may be designed to communicate to the learner what the task is and what the objective of the learner must be if he is to perform it successfully. For example, we may say to the adolescent in the first stages of driver training, "Steer the wheel of the trainer so you always stay on the road and in your righthand lane. If you go off the road or in the wrong lane, a buzzer will sound. Your job is to keep the buzzer turned off as much as possible."

Such a direction, sometimes called a set or expectancy, gives the learner a simple conception of what the task consists of, or of what he must do in order to be successful in executing the task. It would be very difficult to prove, but we would suppose that the more complex the task, the more valuable such a cognitive orientation would be. Fitts (1962), who, perhaps more than most investigators, has analyzed the dimensions of complex tasks, reports that orientations for beginning pilots that permitted them to "intellectualize" the cognitive components of the task of flying resulted in solo flying occuring earlier than for another group of of student pilots who were not given instructions that offered the same opportunity.

Ausubel (1968) has stressed the importance of emphasizing the potential meaningfulness of verbal material. When the organization and struc-

ture of material, such as that included in textbooks or lectures, is ignored, teachers and students alike frequently treat the task as meaningless and approach it as though the material had to be learned by rote. Although it is an extension of Ausubel's point, the application to the learning of skills seems straightforward. If the overall strategy of skill performance can be made clear to the learner in advance of preliminary efforts at practicing the skill, it should be possible for him to achieve maximum positive transfer from what he already knows that is in any sense pertinent to the new skill to be learned. In our previous illustration of driver education, virtually all children have had extensive practice at steering other simple vehicles such as bicycles and sleds, and they possess at least rudimentary knowledge about the rules and customs of traffic behavior in our culture. In so simple a case, much positive transfer probably occurs almost automatically, but when the skill to be learned is more complex, great advantage can accrue if the trainer provides instructions that assist the learner to see the relationships between what he already knows or is able to do and the task that currently confronts him.

The designer of training materials often wishes to insert instructions within the task. The effectiveness of such instructions depends upon several factors. Verbal instructions may be very helpful if the task is primarily verbal. If, however, as is true of many complex skills, the task is heavily perceptual or motoric in nature, verbal instructions may add little, and may actually interfere with the process of learning. Individuals differ, also, in the medium of instruction that they are capable of being helped by. For many people, instructions that are embedded in an activity instead of being given in directly verbal form are more helpful. Finally, and perhaps of most significance to the present discussion, is

the fact that the simpler the instructions provided are, the more helpful they are likely to be. If the trainer attempts to build into the midst of his materials a theoretical or conceptual background for learning the task, he and his materials are in deep trouble. In such cases, a simple verbal instruction or prompt that helps the learner to overcome a rough spot in the learning is much more effective.

Hilgard and Bower (1966), in a discussion of training in "trouble-shooting" (diagnosing and solving problems with electronics equipment), make a similar observation. They report that in one study trainees were provided with situations to diagnose and were given various possible solutions. They were to identify the best diagnosis, which was then compared with pre-programmed diagnoses offered by experts in the field. The objective of such training was to teach the trainees "to think like the experts." Interestingly, no formal instruction was given to the learners in the theories or concepts of trouble-shooting, although these abound. As Hilgard and Bower comment, "In view of various theories of trouble-shooting...it is a bit disconcerting to have the rather blind 'apprentice' method work so well, though of course the optimal sequence may have had all the necessary 'theory' built into it," (Hilgard and Bower, 1966, pp. 548-549).

The point was well made by an early study of motor tracking (Renshaw and Postle, 1928). Subjects who were simply told to keep the apparatus running were designated "uninstructed." "Instructed" subjects were burdened with a detailed set of instructions. For the learner, such instructions can entail an excessive informational load, and verbal directions have to be translated into instructions to oneself about how to perform. With succeeding days of practice, the error rate of the uninstructed subjects diminished far faster than that for subjects given the detailed instructions.

The Effects of Practice

"Practice makes perfect" is one of the most widely known prescientific generalizations about the improvement of skills. Although the generalization needs modification here and there, certainly there is evidence on all hands that the characteristics of skilled performance that we presented earlier do not emerge unless large amounts of practice with the skill are undertaken. During recent years, the world has witnessed both the Winter and the Summer Olympic Games. Thanks to television, we were able to observe first hand the performances of the world's most outstanding athletes. Time after time interviews with these virtuoso performers revealed that they practice their arts or skills perhaps from three to five or six hours each day. Furthermore, for most of these young men and women, that regime of practice has gone on since they were small children. We might suppose that the world's champion figure skaters and platform divers, to pick examples, have devoted as much as fifteen thousand hours to the practice of those skills. It is difficult to visualize what fifteen thousand hours means. One quick translation is to point out that a child spends about that much time in school from the day his mother registers him in Kindergarten until he receives his diploma from the local high school. How practice affects the performance of a complex task can be seen in Figure 1 on page 10. When subjects practiced mirror drawing once a day, their skill improved regularly over a period of three months. The most impressive example that I have located of how performance continues to improve with practice is to be seen in Figure 2 on page 11.

Few laboratory studies have the capability of following the course of practice over many extended trials or long periods of time. The data shown in the figure comes from an industrial study. What it reveals is that skill

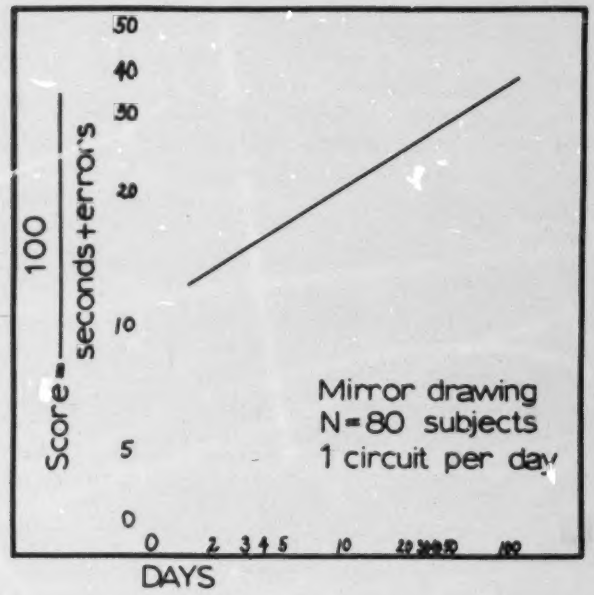

Figure 1: Improvement in mirror drawing as a function of daily practice. (Reproduced from Deese and Hulse, 1967, p.453.)

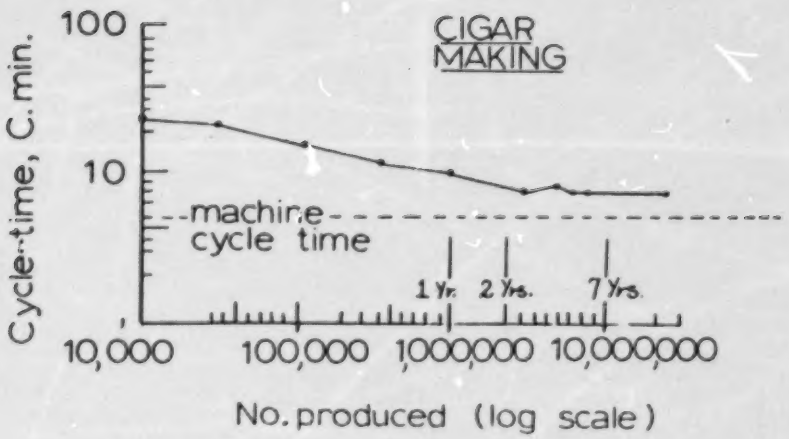

Figure 2: Improvement in an industrial task with repeated practice. (Reproduced with permission from Holding - "Principles of Training" (1965), Pergamon Press Ltd.

in cigar making continues to show improvements through approximately three million trials spread over a full two year period on the job. Nor is that an isolated finding. When industrial or educational studies have examined performance during extended periods of time, involving many, many trials, decrements in time to perform an operation, or in the number of errors made, both of which are traditional indices of improved skill, tend to show up. I suspect, although I have no evidence to submit on the point, that most skills of teaching that we wish students to learn receive absurdly small amounts of practice, far underestimating even reasonable amounts to develop and fix skills at passable levels. One hypothesis I would surely suggest for your examination is that the design of training materials for education of teachers should include estimates of the amount of practice that is likely to be necessary to attain the required level and smoothness of the skill. It would then follow, of course, that the design of the materials should include any conditions that are necessary to bring about the required amount of practice.

One of the earliest observations pertaining to the role of practice in skill learning was the famous study by Bryan and Harter (1897) about learning telegraphy. That was the study that gave us the concept of plateaus in learning. Actually, the plateau that occured there was an artifact of the conditions, or a change in conditions of practice. Later studies of skill and practice have not usually revealed plateaus at all. Of course, whenever we consider the practice records of an individual learner, not smoothed either over repeated performances or by groups of learners, we do not find the steady kind of increment in performance of the cigar making curve. Individual records tend to be quite erratic, but they do show improvement over time if regular amounts of practice continue.

Similarly, we have gradually come to recognize that earlier concepts of motivational and physiological limits of performance are artifacts of particular experimental arrangements.

Knowledge of Results

Perhaps no variable plays a more important role in training on complex skills than that of knowledge of results (Bilodeau and Bilodeau, 1969). Put simply, knowledge of results is information given to the performer about the effectiveness of his performance. In general, psychologists have found that performance improves when the knowledge fed back to the actor has a controlling or directive function over subsequent trials. For example, skills such as target shooting or hitting a golf ball can provide information to the learner about the relationship between his aim, or his swing, and where the bullet or the ball went.

Let us begin the discussion of knowledge of results (KR) with a brief review of one of the ancient but definitive demonstrations of the point. In the 1920's, Thorndike (1927) had people draw lines of 4, 5, or 6 inch lengths while they were blindfolded. Half of these subjects were given no information about their line drawing skill, but the other half were told "right" if the line was within a quarter inch of the criterion, or "wrong" if it was not. Not surprisingly, the line-drawing performances of the group given information or knowledge of results improved, but that of the other group did not (although the performance of that group stabilized, which is frequently overlooked). A few years later, Trowbridge and Cason (1932) refined and extended the original investigation, the results of which are summarized in Figure 3 on the next page.

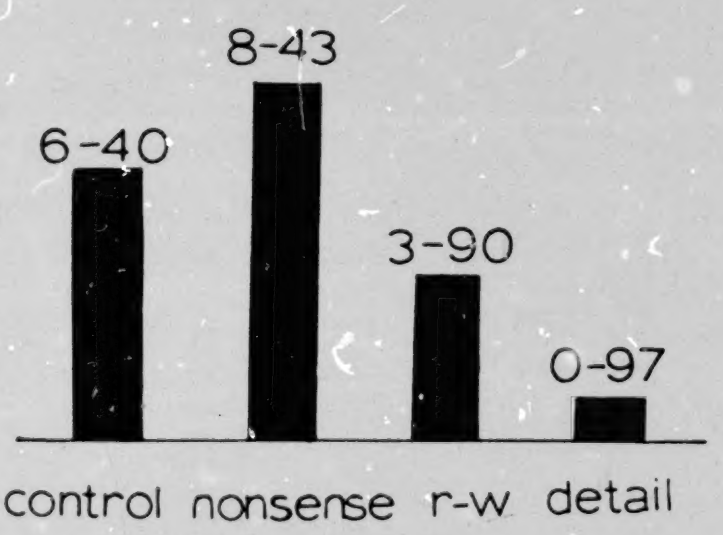

Figure 3: Mean errors in line drawing by subjects given different kinds of knowledge of results. (K. R.) (Reproduced with permission from Holding - "Principles of Training" (1965), Pergamon Press Ltd.)

The control group in the figure was the same as Thorndike's group with no KR, while the group labeled R-W was given the same kind of feedback about their performance as his KR group. Trowbridge and Cason, however, did two things differently than Thorndike. For one group, not only was KR provided, but it indicated in detail how much too long or too short the line was. You can see from the figure that this kind of knowledge reduced the number of errors that people made. The group labeled "Nonsense" was another control group, given not substantive feedback about performance, but simply a nonsense syllable response after each trial. This was done to control for the possibility that any kind of verbal response after an attempt would reduce errors. Since the results for that group were no better than the control subjects (in fact, somewhat worse) the possibility can be dismissed. These studies and others similar to them have demonstrated the value, even the necessity, of knowledge of results for the improvement of skilled performance. But the issue is a complex one. Many motor skills provide a type of feedback as the result of a chain or sequence of events and, while the information may be of a generally instructive nature, often it provides little specific information about how the performance of the skill should be altered if it is to be improved. Consider a relatively simple performance such as basketball free throws. If the ball does not flow through the hoop, a certain amount of information is available from where it does land. If it fails to reach the basket, throw harder. If it hits the front of the rim, try a higher arc. If it bounces off the backboard, use less force, and so on. This general kind of information coupled with hours of countless school boys through the years. But how much greater could the improvement achieved be if the learner received feedback about each element

in his performance? Suppose, for example, a buzzer sounded each time the boy gripped the ball incorrectly, held it too firmly or too loosely, thrust it backward too far before shooting, etc.? We may leave it to the physical education department and the basketball coaches to work out the technology for providing such feedback to their players, but the point has wide applicability with respect to complex skills.

Psychologists frequently talk about intrinsic feedback and artificial (sometimes augmented) feedback. Artificial feedback can help improve performance quickly. The difficulty is that unless the augmented feedback assists the learner in developing his responses on the basis of the intrinsic elements of the task, augmented feedback has little residual benefit. For example, in a study of aircraft gunnery, it was learned that gunnery students had difficulty "framing" the target, this is, setting the correct range for firing. A device that provided an audible click when the proper range was established improved the performance markedly, but when the artificial feedback (the click) was removed, performance dropped off immediately to what it had been for a control group with the same amount of practice. When workers are learning to move unfired pottery, they must not seize it too tightly. In another study, it was found that the correct pressure can be learned if a signal comes on whenever the grasp is too forceful and goes off when the pressure is diminished appropriately. Once an appropriate range of pressures has been learned by the worker, the augmented feedback can be eliminated with no perceptible increase in the number of pots damaged by apprentice workers. Apparently, the worker picks up sufficient proprioceptive cues associated with "signal on" and with "signal off" conditions to behave independently of such artificial cues after a period of learning.

The critical point, of course, is not whether augmented feedback is advantageous, for its use is indicated with many sorts of complex skills; rather, the problem that confronts the trainer is how to guarantee that the learner will integrate the appropriate responses with intrinsic elements of the task. This would seem to be a vastly important observation for producers of training materials in teacher education.

Finally, we must raise the question of when feedback or knowledge of results should be administered. There are two fundamental conditions under which this might happen. First, feedback may be given as the skill is being performed. The previous examples of signals on and off during "framing" or moving pottery involved such concurrent feedback. Alternatively, the training material might not provide feedback until the end of the performance. In this connection, does it matter whether the feedback is immediate or delayed?

Concurrent feedback is important for the action elements of performance, that is, for matching performance to the standards set for the learner. But, for relatively simple tasks at least, learning is more influenced by knowledge of results that succeeds the performance. This finding is not independent of the necessity that the learner base his performance upon cues intrinsic to the training task.

Whether or not knowledge of results must be administered immediately after the completion of the performance is a more critical question for studies with lower order animals than it is for training human beings. There is evidence that even slight delays (of 30 seconds or less) in providing reinforcement to animals after performing a task sharply reduce the amount of learning. However, with human beings, particularly when task performance can be assessed through verbal feedback, brief time de-

lays are of no consequence, and even longer ones, from a day to a week, have been shown not to interfere with learning. That is, verbal feedback can be utilized by human learners to reinstate the original performance, or the learner's retained image of it, and to relate what he was doing with the knowledge of results about it. It does not seem advisable, though, to permit the subject to repeat the performance of a skill before he has received knowledge of results about his first trial behavior.

A Proposal for the Development of Self-Contained Training Materials in Teacher Education

The relevance and applicability to the learning of skills of the concepts of instruction or directions, practice and feedback or knowledge of results has been presented in the first portion of this paper. We shall attempt to organize the second section of the paper around these same topics but modify our discussion of them to fit the special demands of designing training materials in teacher education. As an informal test of the adequacy of these topics as generalizations, we shall try to illustrate how a particular set of teacher training materials might be constructed, and for that purpose we have chosen the skill of teaching concepts. No skill is more ubiquitous in teaching. It is probably safe to say that in better than half of their classroom verbal interactions with students, teachers are attempting to develop concepts in a specific subject area. Concepts such as "subject" and "predicate" in English grammar, "more or less than" in arithmetic, "deciduous" and "evergreen" in botany are examples. The fact that teachers do not always clearly label or specifically define the concepts they teach does not lessen the generality or significance of this activity in teaching. The fact that they do not always teach concepts effectively or efficiently,

on the other hand, is the occasion for us to deal with the design of teacher training materials in this area. First, however, we must give some attention to the nature of concepts themselves and to a model for teaching them.

The Nature of Concepts in Relation to Teaching.

A concept is an abstraction based upon the common properties or elements possessed by all the members of a class, but not exclusively descriptive of any single member of that class. Words are labels for concepts, and definitions are an attempt at the level of logic to identify the genus and differentia of the class.

To teach a concept involves some skills that are unique and others that are common to more general issues in teaching. Among the latter we would include such items as assessing the knowledge of learners before and after instruction, and of seizing upon whatever feedback cues are available in the situation to make instruction contingent upon the comprehension and pacing of the learners.

Skills that are unique to the teaching of concepts would include, at a minimum, the ability to identify concepts and to discriminate those points in instruction at which teaching a concept is the appropriate strategy. Furthermore, the specific task of concept teaching demands that the basic attributes of the concept be explicated, including its limiting cases or conditions. Tactics that would frequently be used to teach concepts, either altogether or in varying combinations, include illustrating positive and negative examples of the concept, defining the concept, and differentiating between the concept in question and others of a similar nature or similar in one or more particulars with which the

target concept might be confused. With this very brief introduction to the teaching of concepts, what implications can we find in the research on complex skill learning for the design of training materials in the teaching of concepts?

Some Assumptions About Transfer, and a Model for Teaching Concepts.

It is important to note at the outset of this discussion that some additional ideas are required to clarify and to complete our illustrative case. In the first place, most skills that we want teachers to master have a conceptual basis. This is certainly true of teaching concepts. For, no matter how many different concepts we choose to incorporate in training materials for teachers, we will never exhaust those that a teacher might be called upon to teach. We assume that a large amount of positive transfer occurs between the training materials that we provide and any particular concept that the trainee later is called upon to teach. Indeed, if we do not make such an assumption, it is difficult to see what benefit would derive from engaging in training.

The theory of transfer of training to which we appeal here is that often called "transfer of principles," "nonspecific transfer," or "generalization." Perhaps we would do well to identify it as a "transfer of model," for what we would do is to train the teacher to make a variety of complex but sequentially dependent responses that conform, on the whole, to the model of the teaching of concepts that we use to plan our training materials. We cannot overemphasize the point that the validity of our training procedures, and their outcomes in educational practice, will be jeopardized to the extent that the models we select are of dubious validity. This fact argues for a continuing and healthy

linkage between research on problems of teaching and the development of training materials, an obvious but usually overlooked problem. In the case of the teaching of concepts, the work of Clark (1971) provides a model for the classroom teaching of concepts. Clark's model is induced from his assessment and interpretation of a large number of experimental studies of concept learning. Unfortunately, few of these studies had their origin in classrooms, and the model developed by Clark is only one of a number that might be developed, and perhaps not the one most pertinent for the training of teachers. The fact that this is so, in a field as carefully studied as the learning of concepts, intensifies the need mentioned earlier for a careful articulation between research and the development of training materials. The first point in our argument, then, is that each concept with which trainees practice can be regarded as a learning trial. What is learned, ultimately, is not simply responses to be made to each of a theoretically large number of trials, but a general model for teaching concepts, one which would obviously have to be modified in particular (and therefore unpredictable ways) from trial to trial, or from one teaching situation to another.

The Clark model for the teaching of concepts includes several elements. The first and last of these are applicable to teaching episodes of any kind, namely that the teacher should in the first place assess the preinstructional knowledge of his pupil and that, finally, there should be an evaluation of how adequately the concept has been learned by the pupil. Between these two assessments, there are basically two components of instruction: an introductory one and a confirmatory one. Both of them are, however, to be guided by some general precepts having to do with offering examples or instances to the learner in a clear,

unhurried and systematic manner. In the introductory stage, all instances should be positive examples of the concept and the critical or criterial characteristics of the examples should be enumerated and explained. The confirmatory process involves gradually mixing negative instances (non-examples) into the sequence of examples and allowing the learner to identify each according to whether it does or does not exemplify the concept. This should be accompanied by complete feedback after each response and with due provision for the learner to consolidate his response to one instance before the next one is presented.

Self-Contained Training Materials and their Place in the Teacher Training Sequence.

Such a model can, of course, be learned by the teacher at several stages that vary on a dimension of classroom or teaching reality. A first stage would be similar to what we have already presented; that is, the teacher could cognize the model in an abstract sense, much as he might learn it from the study of a textbook. A final stage, representing something closer to the concept of mastery that we are after, would have the teacher applying the model in his instruction of real pupils in real classroom settings. Such a stage might be represented in the teaching done by a student teacher or by an experienced teacher in his daily instructional activity. These stages are shown in Figure 4, which also includes Stages 2 and 2a, on page 23.

Stage 2 introduces the notion of self-contained training materials. Self-contained training materials are those materials that allow the learner to practice his skill without reliance upon external agents, such as the availability of a group of students to teach, the presence of a supervisor or other human feedback mechanism, and so forth. We would

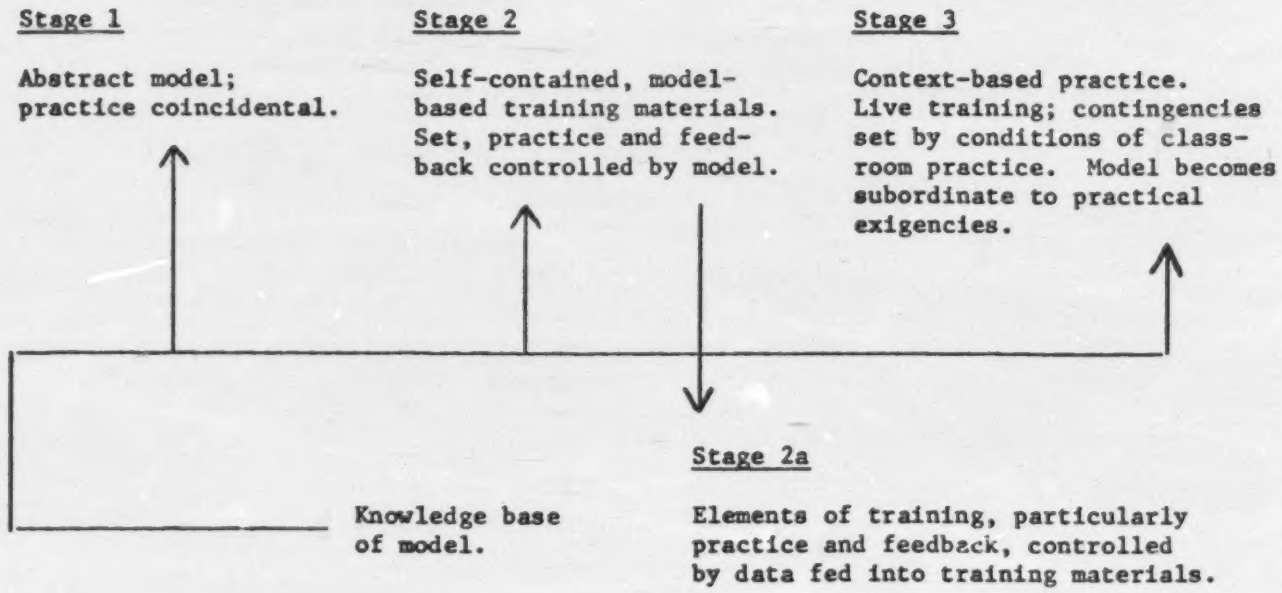
Stage 1
Abstract model; practice coincidental.
Stage 2
Self-contained, model-based training materials. Set, practice and feed-back controlled by model.
Stage 3
Context-based practice. Live training; contingencies set by conditions of class-room practice. Model becomes subordinate to practical exigencies.
Stage 2a
Elements of training, particularly practice and feedback, controlled by data fed into training materials.
Knowledge base of model.

Figure 4: Self-Contained Training Materials in a Teacher Training Sequence. The diagram shows (1.) the dependence of training materials upon an adequate knowledge base for the model and (2.) the position of the materials as the reality dimension of training is varied.

wish to hedge this definition to the extent of excluding from the category "external agents" such equipment as computer terminals or machinery associated with programmed instruction, for the benefits to be gained from using such equipment may be sufficiently great to offset the necessary demands on space and physical housing. But the basic sense in which we use the term "self-contained" is no different from the simple arrangements under which one can ordinarily practice playing a musical instrument or work on a variety of motor skills. The pianist needs only his piano, and perhaps his music, to be in business. The basketball player can practice free throws for hours on end, given only access to a basketball and a standard and hoop through which to throw it.

It is possible to provide training materials with the same advantages for teachers, if certain conditions are met. These conditions may be of two kinds, represented in the figure by Stage 2 and Stage 2a respectively. To provide practice at Stage 2, several fundamental elements are required. These are, first of all, a model of the skill to be learned. For the teaching of concepts, the model of Clark is illustrative. Again we must emphasize that the base of knowledge upon which such models are constructed is of paramount significance. This is true because both the responses that are called for by the training materials and the kind of feedback that is built into them must be derived directly from the model. That is, the contingencies of practice and of feedback are model-based. If the model does not provide skill development that is congruent with the way the skill must function in real situations, negative rather than positive transfer may well result.

Secondly, the training materials themselves must be prepared in accordance with the elements of the model. One does not teach concepts in general, and the training given to the teacher trainee must indicate a specific concept to be taught. It is incumbent upon the developer to analyze each concept and to prepare feedback that will be meaningful to the trainee. In the case of our illustration of the teaching of concepts, for example, the developer would wish to write out a series of illustrative positive examples of each concept which the trainee could use for purposes of comparison with his own examples of the concept.

The necessary condition for materials developed at Stage 2a is that such materials be based upon direct experience by the developer or his staff in teaching the concept. Such experience is not intended to take the place of research on the model of the skill and it does not refer to the base of knowledge upon which the model is built. Rather, the purpose would be to generate some actual data obtained from children when the model is applied to teaching them the skill. These data would take the form of feedback to the trainee.

To summarize (before we finally turn to a more detailed examination of the roles of instructions, practice and feedback in training materials for teaching skills), I believe that the concept of self-contained training materials has two great advantages to recommend it. The first of these is the accessibility to the trainee of extended practice on the skill in question. Some dozen years ago, Shaplin (1961) observed that teachers have relatively little opportunity to engage in the directed practice of teaching. When one asks the question, "How much opportunity does a teacher have to practice a skill such as teaching concepts under circumstances that are aimed at helping him to improve the skill?," the

answer seems to be that the opportunity is quite limited, indeed. Self-contained training materials clearly would allow each trainee to practice to the point of mastering the skill. In the same way, the materials make allowance for individual differences. One's progress is determined only by the amount of practice one requires. Such arrangements clearly make it possible for teacher education programs to begin to individualize instruction for their trainees, and to remove some of the lockstep elements of classroom instruction -- a condition which these same trainees are continually admonished to provide for their own pupils but for which they are almost never provided models as part of their own student experience.

The second great advantage afforded by such self-contained training materials is the occasion they provide for teachers to learn generalized schemes, concepts or models for the skills they are teaching. The probability that teachers will modify their behavior to avoid slavish application of formalistic teaching rises more when they possess the broad image of a skill that is possible from a generalized scheme of it than when what they have learned is merely a set of sequenced behaviors without such a cognitive map. We would add a third advantage, although it may be of less direct significance to the developer of training materials and to the trainees with which they are to be used. This is the hope that the development of models of skills will be carefully accompanied by checks on the knowledge base underlying the model and, where required, that appropriate kinds of research studies will be undertaken to support or to modify ongoing development. As an example of what is intended here, I would point to the work that Gage and his associates accomplished at the Stanford Center for Research and Development in Teaching in their studies of the ability of teachers to explain subject matter. Several

years were devoted to carefully designed experimental studies of the variables that govern explaining behavior. This work was ultimately translated into a training program that conforms in part to the description that we have given here of self-contained training materials.

Designing Self-Contained Teacher Training Materials.

Let us move now to the application of principles established in the first section of this paper to the problem of developing training materials for teacher education. One issue that becomes immediately apparent is that training materials must be specific, not general. Our proposal for training teachers to teach concepts must include practice in the teaching of real and specific concepts, even though its larger objective is to contribute to the development of a broad set of skills that improve concept teaching (and pupils' learning of concepts). Posner and Keele (1973), in a recent major review of skill learning, indicate that their orientation to the improvement of skills through training is to analyze the components of specific skills and to concentrate upon improving performance in the most difficult components.

Therefore, we shall consider the applicability of the factors of instruction, practice and feedback in the context of materials developed to teach specific concepts. For purposes of this discussion, we have selected the related concepts of "latitude and longitude" as the vehicle for training materials. These concepts are not self-evident to children; that is, they must ordinarily be taught formally and they represent concepts of intermediate difficulty for purposes both of teaching and of learning. Furthermore, and of great importance, they are real concepts, both in the sense that they are fundamental to the knowledge and skills of groups such

as cartographers, geographers and navigators, and in the sense that the concepts are customarily found in the social studies or science curriculum studied by children in the middle years of the elementary school. Of course, a program of training materials for the teaching of concepts would necessarily consist of numerous examples of concepts, perhaps some simpler than our illustration, and certainly others of greater complexity. An array of the order implied would be required to offer the teacher in training sufficient practice to master the skills involved in the teaching of concepts and to present concepts for practice in which sometimes one, sometimes another skill or subset of skills, is stressed.

Instructions.

The first consideration bears upon how one represents the task to the trainee. Based upon what we have reviewed, it seems reasonable to infer that the trainee's introduction to the training materials for concept teaching should involve an overview of the nature of concepts and the elements involved in teaching them. Fitts' observation that skill learning begins with a cognitive phase is instructive here. What we wish to do is to make it possible for the trainee to see the task in some perspective. This not only helps to guide his learning, but also maximizes positive transfer. At the outset, written exposition and demonstrations (such as a brief film exemplifying good concept teaching) might assist the trainee to cognize the task we wish him to learn.

Other instructions would probably be desirable and should be embedded at the beginning of different phases or segments of the training material; e.g., prior to the demand to define or illustrate the concept to be taught, or the segment in which presenting positive and negative

examples is to be practiced, and so forth. These verbal instructions should be brief and simple, and will probably be helped immensely if they are accompanied by good examples of the behavior to be invoked.

Directions to the teacher in training provide an outline of the elements of the training task and an advance statement of classes of responses that will be reinforced. The process of training the prospective teacher in the skill of teaching concepts might begin with a direction to him on the order of the following:

> You are going to teach the concepts of "latitude and longitude" to a group of 9 and 10 year olds who may be presumed to be of average intellectual and educational development. Go home and prepare your lesson. Return to this training material twenty-four hours from now. The following information and instructions will assist you in planning your lesson.
>
> A. Write down what your students will be able to do after your lesson to demonstrate that they have mastered the concepts of "latitude" and "longitude."
>
> B. Make a list of the subordinate concepts that contribute to the concepts you are to teach. For example, the pupil must know concepts of direction (North, South, East and West), degrees, hemisphere, etc.
>
> C. For each concept, provide not only a verbal description or definition, but a variety of examples or instances of it as well. In the early stages of teaching the concept, your examples should all be positive; that is, they should illustrate or exemplify the concept. Some of your later examples should be negative (nonexemplars), particularly if they are helpful in differentiating between the concept to be learned and another with which it might be confused.

These or similar instructions are designed to enable the trainee to construct a cognitive map of the task of the order that Fitts reported was useful to fledgling pilots. Another interpretation of sets of instructions of the kind provided here is that they function as discriminative stimuli for the teacher. He is advised in advance, in other words, that his efforts to specify master of the concept, or to analyze

the hierarchy of learnings that contribute to mastery, or to construct examples of the concept, will be reinforced (specifically, that they will lead to positive knowledge of results, or at least the potential for such positive feedback).

Practice.

One of the chief benefits to the prospective teacher of self-contained training materials is their provision for both permitting and encouraging trainees to continue practicing a skill until they have mastered it, or until an acceptable criterion has been achieved. How much practice on a teaching skill such as the teaching of concepts should the design of a program make possible? That, of course, is an empirical question and would have to be answered differently for each skill we attempt to teach. As a general statement, however, I would urge that you define the amount of material available for practice in the most generous terms and then double it, perhaps triple it. If there is any single weakness that I think teacher education programs have, beyond their failure to develop penetrating concepts about teaching, it is their failure to provide prospective teachers with an array of skills that are useful for the solution of instructional problems. Not only are few skills identified, but it is the rare program of teacher education that makes it possible for the candidate to achieve the amounts of practice necessary to build a skill adequacy into his repertory. If you recall the graphs we showed earlier of continuing increments of improvement with large amounts of practice, the point becomes more credible.

To specify in advance the amount of practice required for any given trainee would be impossible and inappropriate, for the aim is to make possible whatever an individual trainee needs, and simultaneously to in-

sure that he engages in practice long enough and productively enough to achieve mastery of the skill. This latter is a point of paramount importance. Training materials must be constructed with an explicit formulation in mind of what the trainee must do to demonstrate that he possesses mastery of the skill. We need not attempt here to delineate standards for determining mastery, but they usually involve statements about the performance of essential characteristics of a skill and about permissible error rates or amount of time within which the skill must be performed. These standards should, of course, be presented to the trainee at the start of practice and they should be sufficiently clear that the trainee himself is as good a judge as anyone of when his performance matches the demands of skill mastery.

For many skills, it is sensible to talk about mastery only when the trainee can perform as desired upon a training task that he has not previously encountered. This would certainly be true for training in the teaching of concepts. For one thing, some of the earliest materials the trainee encounters would be too simple to permit mastery in the fullest sense. Beyond that, however, the skill we are attempting to build is of a general order; that is, the trainee demonstrates the skill when he undertakes to teach concepts as part of the day to day practice of teaching. This consideration necessitates, in the case of skills similar to teaching concepts, that some form of criterion test be available. Those tests, of course, may simply be represented by the first practice concept the trainee teaches within the limits identified for mastery.

Some years ago, I conducted a research project in which we examined the presumed attention-paying behavior of pupils in classes (Hudgins, 1967). The point of this was to try to relate differences in such atten-

tion to classroom variables, such as type of activity, content, rates of activity variation and so forth. One of the daydreams I had about extending the results of the study to the practical training of teachers concerned programming our data in such a way that a student teacher would be confronted with an immediate problem of the ongoing classroom variety and be compelled to construct a "solution" to the problem, which would be fed into the computer. The computer would then feed back the results of the teacher's solution, translated into pupil surface behavior. In its most virulent forms, this daydream dictated that the feedback would be a visual display, showing the student teacher that his tactic put everyone to sleep, had them on the edges of their chairs, and so forth. I still think, if one had the right kind of data and concepts, that this is a good idea. The value of the concepts to be learned would be paramount, but beyond that, and as a secondary asset, if such an arrangement were available, each student could practice his repertory of skills as fully as warranted by his present level of expertness.

The moral is that teaching skills are made most resistant to forgetting when they are overpracticed, that is, when practice continues well beyond the stage at which the basic elements of the performance are fixed. As you design training materials, it is critical that attention be given to ways of insuring that the learner can build his practice schedule in terms of the needs of his level of skill and his motivational state. The more he must rely upon coordination of others' time, involvement, the reservation of equipment or facilities, the more impediments are built into his practice. These elements combine geometrically, so that by the time practice is made contingent upon bringing together two or three outside resources, you have virtually insured that no practice will occur.

This consideration, in my opinion, so far overshadows issues such as whole vs. part practice, or massed vs. distributed practice, that you ought only to consider their pertinence when you are satisfied that the necessary prerequisites for self-determined practice schedules are available.

Let us stop here to anticipate an objection to the line of argument we are building. The thesis is that teachers receive relatively little guided practice in learning skills of teaching and that self-contained training materials can go a long way toward reducing the negative consequences of that fact. Obviously, this general principle is well known in many daily fields apart from training materials in teacher education. Several that come to mind, for instance, are practice on a musical instrument and numerous motor skills of the kinds involved in athletics. The pitcher may practice for hours until he can invariably hit a small bullseye from 60'6"; the batter enthusiastically hammers baseballs thrown his way by the tireless mechanical pitcher and so forth. But as we have already suggested, college students and others who aspire to teach are ordinarily able to acquire little in the way of directed practice in teaching, and that little frequently occurs around rather general tasks, such as "teaching a whole group," "leading a reading group," etc., instead of the precisely defined tasks of teaching made possible by the design of training materials.

A reasonable question to raise is whether teaching can be conducted in a meaningful way in the absence of some kind of audience cast in the role of pupils or learners. That is, one might agree with everything we have said from the viewpoint of logistics but feel compelled to disagree in a fundamental sense that skills in teaching can be developed in the

absence of pupils. It may be useful to distinguish between learning the principles of a skilled performance and learning to perform the skill in the context in which it normally is practiced. Self-contained training materials make possible the first sort of practice but not the latter. A legitimate and useful role exists for self-contained training materials provided that we are cognizant of this distinction and do not erroneously attribute the effects of context-based practice to it. It is quite clear that trainees who practice the teaching of concepts with self-contained materials must at least exhibit mastery of the skill in a contextual setting and may require some practice in such a setting before they are able to apply the principles learned in their earlier practice to more realistic situations containing, as they do, "warts and all." It is an empirical question as to how comparable are units of self-contained practice with units of what we have called context-based practice. We would hypothesize that the latter form of practice possesses little if any advantage over the former, but even if that contention cannot be supported, the earlier ventured benefits of self-contained practice lend it a great advantage. In the final analysis, the amount of time devoted to practice is less critical than the accessibility of the trainee to meaningful practice. To put it practically, a student can achieve mastery of a teaching skill if he can practice it with the same ease he can read a book in the library, in a fraction of the elapsed time required for complex practice arrangements even though the learning curve is more sharply accelerated in the latter situation.

A related question concerns the mode or format of practice. Self-contained materials will often be remarkably simple and, although they must require responses from the trainee that are cognitively identifiable

with the responses that are made in performing the skill in actual teaching situations, the mode of responding will typically be very different and very much simpler. For example, the trainee may construct a written response which is then compared with a predesigned array of potential responses, and he may respond much as he would to multiple choice items in an examination or in programmed instructional materials. Once again, the hypothesis is that the trainee learns generalizations and basic principles about the skill which will transfer positively and in large measure to context-based practice although to be sure it must be demonstrated that the practical exigencies of the teaching situation can be mastered by students so trained.

Knowledge of results.

As necessary as practice is to the development of teaching skills, its impact can be greatly intensified if the design of the training material builds in appropriate types of information about performance. It is common to say that teaching performance suffers from an absence of feedback, but I disagree with that. I believe one of the difficulties with changing the behavior of experienced teachers is that they receive too much of the wrong kind of knowledge of results. Most of the feedback teachers receive is what Holding (1965) would call action feedback rather than learning feedback. To put it a little differently, I think teachers receive feedback about style rather than about learning. Time and again, when we ask teachers how they know whether a lesson goes well or poorly, the responses are the same. "When the kids wave their hands, when they're halfway out of their seats, when they're popping with answers and ideas, then you know it's going well." We all like the feelings of success that such feedback provides, but it is doubtful that the informational value

for shaping the fine-grained behavior required in excellent teaching is provided by it.

What can we say about knowledge of results that would be of such informational value in training materials? Of course, the single most important decision is the one to insure that feedback is provided as the learner practices his skill. The difficulty, as we have already tried to clarify, is that most teaching performances have very little in the way of intrinsic cues to provide feedback. Thus, the trainer is going to have to depend heavily upon augmented or artificial knowledge of results.

In the early stages of learning to teach concepts, for example, we might wish to insist that the trainee always assess the pre-instructional knowledge about the target concept of his subjects. If he fails to do so, there may be a signal that brings this fact to his attention. In a real teaching situation, of course, it is unlikely that any such signal would be available. Similarly, one needs to invest patience and a degree of divergent thinking in concept teaching at least at two points: when providing positive and negative examples and when arraying interfering or overlapping concepts which are to be differentiated from the target concept. Some of the best concept teaching episodes arise when students become involved in questioning examples, in inquiring whether X or Y would also be an example, or in challenging the teacher's assertion that A is similar to the target concept in these ways and dissimilar in others. Such questions and challenges from pupils have a disciplining effect on the teacher's behavior, forcing him to engage in the fine grain of concept teaching which is absolutely critical to its being done competently. One cannot depend, of course, on monitoring of that sort occuring on the part of pupils. In training, at least, the would-be teacher must receive

feedback that tells him not only whether he has engaged the basic elements of the skill, but also how effectively he has done so.

With skill training that is model based, divergent responses by trainees are both inevitable and desirable. How the developer can prearrange feedback that will be useful and meaningful under those circumstances poses a very difficult problem. However, it is a problem exactly analogous to that faced some years ago by psychologists engaged in constructing tests of creative thinking. By definitions, of course, creative responses are divergent responses. The work by Torrance (1966) on this score is instructive. The scoring manual for his tests of creative thinking includes some general conception of responses that are allowable for the various factors scored (for example, originality) but, in addition, the manual contains several pages of specific responses that would be given originality scores and of responses that are not to be counted as original. True, the Torrance Keys are constructed on the basis of responses of a large sample of individuals who took the Torrance Tests of Creative Thinking and, thus, the key has an empirical basis. This procedure is probably closer to what could be done in Stage 2a of our diagram. On the other hand, even at Stage 2, responses will be generated for the various elements of the model. The problem for the developer is to produce exhaustive responses generated by the model and to manage their ordering and display in such a way that they can provide appropriate feedback to the trainee. Again, this is a difficult problem, but the example of Torrance and the scoring of tests of creative thinking suggest that it is by no means an insuperable one.

It is helpful, I hope, to have some possibly different ideas about considerations in the design of training materials, even though the practical problems presented are awesome. For I think we will be willing to

make the investment of time and energy in designing and producing training materials if there is some hope that they will ultimately do their task more effectively.

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